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Horticulture for Pollinator Conservation

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HORTICULTURE FOR POLLINATOR CONSERVATION

by

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Pollinators worldwide are declining. Consequently, the agricultural and ecological services these insects provide are in danger of being lost. Land use intensification, via urbanization, has greatly influenced this decline in pollinators. Luckily, through targeted horticultural practices, stable populations of pollinators can be sustained within urban areas. The horticultural practices of planting diverse floral resources and managing pollinator habitat in urban areas can sustain these populations. Two studies were conducted with the intent to identify horticultural knowledge gaps that could be reduced to aid in pollinator conservation efforts. First, a study to compare Nebraska native and non-native ornamental plants was conducted. This study set out to understand the impact a plant's native status has on its attractiveness to urban bees. Three pairings of plant species with similar flowering attributes were sampled for bees. Each pairing included one native plant and one non-native plant. The average abundance and diversity of bees per observation was compared. Results between pairings were mixed, suggesting the native origin of a plant species has little to no impact on attractiveness to urban bees. A weak correlation was discovered between various plant attributes and the abundance and diversity of foraging bees, suggesting plant qualities apart from native origin may be at play. Our recommendation is to use a diverse palette of native and non-native plant species that includes select plant species that attract specialist bee species. Second, a nationwide survey of horticulture retail employees was

conducted. This survey aimed to assess the knowledge retailers possess pertaining to pollinators and to determine what plant and landscape recommendations they are giving customers for pollinator conservation. Responses were analyzed with demographics to determine discrepancies in knowledge among specific groups of employees. Overall, pollinator knowledge and conservation recommendations were accurate, but room for improvement was identified, suggesting opportunities for educational outreach. There still is much work to be done to improve horticulture practices that aim to conserve pollinators. These two studies serve as a starting point for future research projects. Horticulture can be an extremely useful method of promoting and increasing pollinator health. By conducting and implementing further scientific research, this scientific discipline can be used more effectively.

Table of Contents

Literature Review

Chapter 1.

Insects provide many ecological services. These services include recycling soil nutrients, controlling pests, and pollination. Pollination is an invaluable service, one that facilitates the reproduction of nearly 87.5% of the world's plant species (Ollerton, Winfree, & Tarrant, 2011), and 35% of the world's agronomic crops (Klein et al., 2007). The estimated value of insect pollination has been estimated to be worth between $18 and $27 billion annually in the United States alone (Mader, Shepherd, Vaughan, Black, & LeBuhn, 2011). In short, insect pollination directly influences the health of all terrestrial ecosystems, global food security, and world economies.

There are four insect orders that contain species that are known facilitators of pollination. These orders include Hymenoptera (bees and wasps), Diptera (flies), Lepidoptera (butterflies and moths) and Coleoptera (beetles) (Mader et al., 2011). Although insects belonging to all these orders are required to ensure pollination of all plant species, no insect group is as wide-spread, numerous, and efficient pollinators as the Hymenopteran superfamily Apoidea, the bees. These insects deliberately collect pollen as a food source for their young, and possess specialized appendages for collecting pollen. Some species of bees visit a single plant species in one foraging trip (Mader et al., 2011). This behavior, known as flower constancy, reduces the amount of wasted pollen. Transfer of pollen among plants is much more incidental in other insect groups, being based almost entirely on chance.

Like any other insect group, there is diversity within bees. There are over 4,000 species of bees in North America alone (Joseph S Wilson & Carril, 2015). Out of these

4,000 species, both polylectic and oligolectic species exist. Polylectic bees are highly advantageous, and will forage on a variety of plant species. Oligolectic bees, in contrast, forage on a narrower spectrum of plant species. In some cases, bee species are so specialized that they will forage only on a single species of plant. Thus, these specialized bees are the only facilitators of reproduction for one plant species and that one plant species is the only food source for that species of bees.

Between the annual loss of about 30% of managed beehives in the United States (Kulhanek et al., 2017), and the listing of the rusty patched bumblebee as an endangered species, there is evidence that various populations of bees are in decline. Bee decline is due to environmental and human-caused stressors; including climate change, infectious diseases, introduced parasites, exposure to pesticides, and a lack of floral resources and nesting habitat, which is believed to be the greatest contributing factor (Goulson, Nicholls, Botías, & Rotheray, 2015; Vanbergen & Initiative, 2013). These stressors negatively influence bee health, affecting their abundance and diversity (Vanbergen & Initiative, 2013).

Landscapes in cities and suburbs are heavily controlled by humans, and lack the abundance and diversity of floral resources to support a diversity of healthy bee populations (Clough et al., 2014). These highly disturbed environments not only diminish bee populations, but also shift the structure of bee communities. The lack of floral diversity makes these areas more favorable to polylectic species, which homogenizes bee communities. This homogenization reduces the amount of oligolectic species present, diminishing bee diversity. (Deguines, Julliard, de Flores, & Fontaine, 2016; Jędrzejewska-Szmek & Zych, 2013).

The sheer presence of plants in these intensively used lands can also positively impact bee populations. While city and urban landscapes use can lead to poor bee abundance and diversity, landscapes can support healthy bee populations if managed correctly (with proper floral and habitat diversity) (Ahrné, Bengtsson, & Elmqvist, 2009; Baldock et al., 2015; Banaszak-Cibicka & Żmihorski, 2012; Davis et al., 2017; Eremeeva & Sushchev, 2005; Fortel et al., 2014; Frankie et al., 2009; Geslin, Le Féon, Kuhlmann, Vaissière, & Dajoz, 2015; Gunnarsson & Federsel, 2014; Jha & Kremen, 2013; Lowenstein, Matteson, & Minor, 2015; Lowenstein, Matteson, Xiao, Silva, & Minor, 2014; Persson, Rundlöf, Clough, & Smith, 2015; Potter & LeBuhn, 2015; Sirohi, Jackson, Edwards, & Ollerton, 2015; Threlfall et al., 2015; Tommasi, Miro, Higo, & Winston, 2012; Williams & Winfree, 2013; Wojcik, Frankie, Thorp, & Hernandez, 2008; Wray & Elle, 2015). Due to the relatively small functional requirements, habitat range, short life cycle, and nesting behavior of bees, urban areas can be designed to support bee populations (Hall et al., 2017).

While planting a diversity of blooming plants in urban landscapes is generally a good pollinator conservation practice, not all plant species provide adequate nutrition to sustain bee populations. For example, popular urban landscape plants including tulips (*Tulipa*) and petunias (*Petunia*) have been found to provide little nutrition to bees (Tommasi et al., 2012). Previous studies have explored landscape and/or plant attributes that influenced the support of bees. Some of these studies investigated how the presence of native plant species and non-native/introduced plant species influenced bee abundance and diversity.

Although previous research efforts surveyed the abundance and diversity of bees visiting native landscapes and landscapes containing introduced plants, the results were conflicting. A 2015 study discovered that using only native plant species may not be ideal for provisioning resources for a diversity of bee species, stating that introducing non-native plants into landscapes could extend flowering seasons and potentially provide forage for more oligolectic bee species, depending on the plant species (Salisbury et al., 2015). In contrast, a 2014 study found a higher abundance of native bees in landscapes with more native plants, as compared to landscapes with more non-native plant species, but no significant difference in the diversity of bee species existed between the two landscape types (Pardee & Philpott, 2014).

The mechanisms that impact a landscape's carrying capacity for bees is not completely understood. The discrepancies between the two studies mentioned highlights a specific knowledge gap, which raises the question, 'How does the origin of a plant species impact its ability to support bee populations?'

Chapter 2

In recent years, much public attention has been focused on pollinating insects, the facilitators of plant reproduction. Part of this attention is due to colony collapse disorder in honey bees. Since 2006, beekeepers have been reporting an average annual winter loss of 30% of their hives (Kulhanek et al., 2017). In addition, other charismatic insect pollinators, including monarch butterfly populations, have been declining since the mid-1990s (Brower et al., 2012). In June of 2014, President Obama issued a memorandum that established a task force focused on pollinator health to create a nation-wide strategy to conserve the nation's honeybees and other pollinators (WhiteHouse, 2014). This memorandum lead to the creation of the Pollinator Health Task Force, an inter-departmental task force including representatives from thirteen different governmental agencies.

Public concern about pollinator declines and the resulting detrimental impacts is warranted. Pollination as an ecological service is necessary for maintaining ecosystem health and for ensuring food security. Thus, it is imperative that pollinators be protected and their health supported through scientific research and conservation practices.

The decline of pollinating insects is suspected to be a result of intensified land usage, like urbanization, where floral resources are low in abundance and diversity. North America has the highest amount of residents living in cites, with 82% of the population living in urban areas (Nations, 2014). Nearly one quarter of the United States' land area consists of land that could potentially be put to use in conserving pollinators (Bigelow & Borchers, 2017). These urban, suburban and rural areas consist of parks, schools, businesses, but is mostly comprised of privately owned property, with yards. The vast majority of this land is underutilized, and with targeted landscape practices, these lands can be used for conservation. Homeowners are willing to have their landscapes take on an ecological role. A study found a majority of homeowners are willing to have ecologically beneficial landscapes, regardless of cost, like planting native plants (Helfand, Sik Park, Nassauer, & Kosek, 2006)

Pollinator conservation in the home landscape may be a challenge for homeowners, due to the complexities of knowing which plants are beneficial to pollinators, how to design landscape features beneficial to pollinators, how to manage a pollinator habitat, and how to reduce chemical inputs. Expecting a large percentage of homeowners to have the knowledge and skills necessary to design and manage pollinator habitat is unrealistic, as it is not common knowledge. To support this, a 2017 survey of college science majors found deficiencies in knowledge of both pollinator biology, as well as conservation practices (Golick, Dauer, Lynch, & Ingram, 2017). A combined lack of knowledge about pollinators, landscaping, and landscape practices to sustain pollinator habitat is a barrier to implementing sound pollinator conservation practices such as planting pollinator habitat and forage plants. Homeowners use many convenient resources, including websites, books and workshops. Among those convenient resources are online plant lists that recommend plants for pollinator habitats. A 2014 study found that although many of these lists had good plant selections, they were not complete, and omitted many plant selections. (Garbuzov & Ratnieks, 2014). The most common source for landscape information often comes from the point of sale of their landscape materials (Meyer & Foord, 2008). This places employees and resources in horticulture retail stores in a prime position to provide education on the subject of pollinator conservation as an important part of landscaping.

Staff subject knowledge on subjects including plant recommendations and landscape practices is a concern for garden center customers (Barton, Brooker, Hall, & Turner, 1998; Safley & Wohlgenant, 1995). A 2007 study of Connecticut horticulturalists found that there were some gaps in knowledge of invasive plant species within the nursery trade. As an example, a small percentage of garden center staff believed Japanese silver grass (*Miscanthus sinensis*) and butterfly bush (*Buddleja davidii*) to be invasive (14.5%) and (8.1%) respectively, despite their invasive status in Connecticut (Gagliardi & Brand, 2007). Although unrelated to pollinator conservation, this shows that there may be some knowledge gaps in plant selection in the horticulture industry. Plant selection is integral to pollinator conservation, as not all plants provide adequate forage for pollinators, and current recommendations may not be wholly accurate.

Public interest in pollinator conservation has increased markedly in the past decade (Joseph S. Wilson, Forister, & Carril, 2017). If this trend is to continue, the number of homeowners seeking assistance in pollinator conservation should be expected to rise as well. We expect retailers to have proficiency in serving their customers, as it is their primary concern. However, retailers' proficiency to serve customers wanting to use their landscape to conserve pollinators is unknown. In order to gauge retailers' knowledge on this subject, a nationwide survey of horticulture retail employees was developed and conducted. The objectives of this survey were to: 1) discover what plant choices and management recommendations employees were giving customers pertaining to pollinator conservation, 2) assess employee knowledge about pollinators and pollination biology, and 3) determine where to focus possible education and outreach efforts on specific aspects of pollinator conservation.

Chapter 1. Do Native Plants Attract More Bees? A Comparative Study of Native and Non-Native Ornamental Plants

Abstract

Insect pollination is a crucial ecological service. Pollination results in production of many foods, which provide humans with a diverse diet, and pollination allows reproduction of wild plants. Bees are the most efficient pollinating insects. To ensure food security and maintain healthy ecosystems, bee conservation must be a priority. Currently, numerous factors negatively influence bee population sizes, with loss of habitat and forage being the greatest contributing factors. Bees can be conserved through horticultural practices such as providing floral resources and habitat. This study aims to improve conservation efforts by comparing the abundance and diversity of bees among native and non-native ornamental plants. In this comparative study, three pairs of plant species with similar attributes, apart from their origin (native or non-native) were sampled for bees across various sites in Lincoln, Nebraska. Abundance and diversity varied among plant pairings, with the native plant having a higher abundance and diversity in one pairing, the non-native plant in another pairing, and no significant difference in the final pairing. Weak correlations were found between various plant attributes (height, spread, and number of flowers) and abundance and diversity of bees. We conclude that a plant's native origin may have little to no influence on its ability to attract bees, whereas other plant attributes may have greater influence. To design landscapes to support bees, we suggest using a diversity of native and non-native plant species as the best option to conserve urban bees.

Introduction

Pollination is an invaluable service, one that facilitates the reproduction of 87.5% of all the world's plant species (Ollerton et al., 2011). 35% of the world's agronomic crops are produced via pollination as well (Klein et al., 2007). The monetary value of insect pollination is estimated to be worth between $18 and $27 billion annually, in the United States alone (Mader et al., 2011). In short, insect pollination directly influences the health of all terrestrial ecosystems, ensures global food security, and is integral to world economies.

Between the annual loss of about 30% of managed beehives in the United States (Kulhanek et al., 2017), and the listing of the rusty patched bumblebee as an endangered species, there is evidence that this specific group of pollinators, as well as others, are in decline. This decline is due to any number of environmental stressors which negatively impact bee health, resulting in a loss of abundance and diversity of species (Vanbergen & Initiative, 2013). These stressors include climate change, infectious diseases, introduced parasites, and exposure to pesticides. (Goulson et al., 2015; Vanbergen & Initiative, 2013). All of these stressors in turn are heightened by a lack of proper nutrition for bees (Goulson et al., 2015). This lack of nutrition is attributed to the lack of diverse floral resources, caused by intensification of land use, like urbanization (Clough et al., 2014; Goulson et al., 2015).

Landscapes in urbanized areas are heavily controlled by humans, and lack the abundance and diversity of floral resources that support healthy and diverse bee populations (Clough et al., 2014). These highly disturbed environments not only diminish population size, they also shift the community structure of bees. Environments with low floral diversity are more favorable for polylectic (generalist) species of bees. This reduces the amount of oligolectic (specialist) species present, as well as overall bee diversity, thereby homogenizing communities. (Deguines et al., 2016; Jędrzejewska-Szmek & Zych, 2013).

The presence of floral resources in human-dominated landscapes can positively impact bee populations. Numerous studies have found that when appropriate floral resources are present, urban areas have the capacity to support healthy bee populations (Ahrné et al., 2009; Baldock et al., 2015; Banaszak-Cibicka & Żmihorski, 2012; Davis et al., 2017; Eremeeva & Sushchev, 2005; Fortel et al., 2014; Frankie et al., 2009; Geslin et al., 2015; Gunnarsson & Federsel, 2014; Jha & Kremen, 2013; Lowenstein et al., 2015; Lowenstein et al., 2014; Persson et al., 2015; Potter & LeBuhn, 2015; Sirohi et al., 2015; Threlfall et al., 2015; Tommasi et al., 2012; Williams & Winfree, 2013; Wojcik et al., 2008; Wray & Elle, 2015). Due to the relatively small functional requirements, habitat range, short life cycle, and nesting behavior of bees, urban areas can be suitable for bee conservation (Hall et al., 2017).

As the presence of floral resources in urban areas can make such a positive impact on bee populations, it is imperative that urban landowners use the proper plant species for bee foraging. Not all plant species provide good nectar and pollen nutrition for bees. For example, popular landscape plants, like tulips (*Tulipa*) and petunias (*Petunia*) have been found to provide little nutrition to bees (Tommasi et al., 2012). Many attributes such as plant species, variety, floral shape, nectar and pollen shed periods, and origin have been suggested as influences on whether a plant is visited by and of adequate nutritional value to bee populations. Perhaps the most controversial attribute is whether the native or non-native origin of a plant to a specific locale makes it a good plant to support pollinators.

A few studies have explored the impacts of native and non-native plants on supporting various bee populations. Prior research efforts have surveyed the abundance and diversity of bees visiting native and introduced plant landscapes, and the results varied. A 2014 study found higher abundance of native bees in landscapes with more native plants, as compared to landscapes with more non-native plant species, but no significant difference was found in the diversity of bee species between the two landscape types (Pardee & Philpott, 2014). A 2016 survey of pollinators in urban gardens found a correlation of higher abundance of native pollinator in gardens with more native plants as well (Fukase & Simons, 2016). A 2005 survey of urban gardens in California found North American bee species exhibited some preference toward native ornamental plants, but still visited non-native plants (Frankie et al., 2005). This may support the claim made from a 2015 study, where it was concluded that properly selected non-native plant species may lengthen the flowering season and provide forage for pollinators for an extended period of time (Salisbury et al., 2015).

The mechanisms that impact a landscape's carrying capacity for bees is not completely understood. The discrepancies between the two mentioned studies highlights a specific knowledge gap. Therefore, there is a need to determine the attributes of a plant that affect its attractiveness as a food plant to bees. In addition, there is a need to determine whether the origin of a plant species impacts its ability to support bee populations. The purpose of this study is to explore the impacts a plant's native status has on attractiveness to bees.

This study's primary objectives are to: 1) compare and contrast the abundance and diversity of bees between two similar plants (of the same plant group) of Nebraska native and non-native ornamental herbaceous plants, and 2) to determine the correlation between the plants' size, number of blooms present, and nectar sugar quality and the diversity and abundance of bees attracted to these plants. .

Methodology

Test Sites. Three sites were selected in Lincoln, Nebraska, and one in the small community of Waverly, Nebraska, located northeast of Lincoln (Figure 1). Sites were selected based on available space and full sun exposure. The first test site was located in central Lincoln, near the University of Nebraska-Lincoln East Campus Pollinator Plot and Outdoor Classroom (40°49'43.3"N 96°39'22.6"W). This site was located near maintained turf grass, a nut and fruit orchard, and a large pollinator habitat/outdoor classroom with managed honeybee hives roughly 130 meters away. The second test site was also located on the University of Nebraska-Lincoln East Campus. This site was located within the Backyard Farmer Display Garden, which is a large display garden with a diversity of perennials and annual landscape plants (40°49'50.6"N 96°39'53.9"W). The third site was located at the Nebraska Game and Parks Outdoor Education Center in central Lincoln (40°51'28.1"N 96°39'32.9"W). This area was located adjacent to a creek surrounded by woodlands, and a high traffic street. The fourth site was located in Wayne Park in Waverly, Nebraska (40°54'27.5"N 96°31'42.6"W). The park consisted of managed turf grass, and an assortment of trees and shrubs.

Each site contained a 3.65 by 7.32 meter area that received full sun exposure (Figure 2). These plots were constructed by eliminating turf grass and cultivating the soil using a common garden tiller. Plants were purchased from local retailers and planted in May of 2016. Four plants of each species were planted at each location. Plants were arranged in a random order, and were spaced 0.6 meters apart. Plants were given a 14-14-14 fertilizer application at planting. Plots were maintained by periodic watering and wood mulch was applied to conserve soil moisture. Weeds were controlled by hand-pulling and light applications of glyphosate were administered as needed according to label directions to prevent weed competition throughout the 2016 and 2017 growing seasons.

Plant Species. Eight perennial and herbaceous plant species were selected from the family *Asteraceae* and *Lamiaceae* were chosen based on their known attractiveness to bees (Frankie et al., 2009). Of these, three plant pairs were created, each containing one native plant species and one comparable non-native plant species from the same family (Table 1). Plants within each pair had an overlapping bloom period, were similar in bloom color, and had similar flower shapes. These plant attributes were expected to impact visitation and were standardized to the extent possible to avoid any biases. All species had relatively similar requirements, needing full sun exposure and requiring little supplemental water. These attributes made them especially suited to eastern Nebraska's climate, reducing the amount of management required during the study. *Monarda didyma, Monarda fistulosa*, *Perovskia atriplicifolia, Salvia azurea,* Aster X*dumosus,* and *Symphyotrichum novae-angliae* were the selected species (Table 1).

Data Collection. Data collection took place on a weekly basis during each plant pair's respective bloom period. Data were collected for four consecutive weeks or until the plant species stopped blooming, whichever came first. Collection took place during the growing seasons of 2016 and 2017. Collection times were dependent upon the ambient temperature and weather conditions. Collections usually took place between 9:00AM and 2:00PM when temperatures were between 16°C and 32°C. Data collected later than 2:00PM were often too hot for many insect species to remain active. Late summer and autumn collections usually took place once daytime temperatures rose above 16°C. Temperatures below 16°C are too cool for some species of bees to become active. In the event of poor weather conditions such as rain, data collection was postponed until the next day where weather conditions fit our parameters.

To reduce sampling bias due to time and temperature differences, the order of sampling from sites were randomized for each collection date. The data collected at each site for each date consisted of recording weather conditions, insect sampling, plant sampling, and sampling for nectar from each plant.

The weather conditions including temperature, cloud cover, wind speed, and dew point were recorded upon arrival at test sites. Insect sampling consisted of observing each blooming plant for a three-minute period and collecting, with butterfly net, all bees landing on the plant within that time period. Collected specimens were then dispatched using a jar of ethyl acetate. Specimens were then transferred into bags labeled with pertinent information (plant species, number, plot, and date of collection). Plant attribute data (plant height, spread, blooming flower count, and sugar content of nectar) was collected for each plant following insect collection using standard measuring tape. Flower counts for plants were estimated for plants with many flowers. Sugar content of nectar was measured by collecting mature flower samples from each plant. To get a measureable amount of nectar from each sample, a pilot study was conducted to determine how many flowers it would take to get a measurable amount of flower nectar from each flower sample. One flower was collected from both *Monarda* species, five flowers were collected from *Salvia* and *Perovskia* during every observation, and three flowers were collected from *Symphyotrichum* and *Aster*. Flowers were stored in labeled 100 mL sampling cups in a cooler until they were taken to a laboratory for processing.

Following data collection, bee and flower samples were taken to a laboratory for processing. Flower samples were prepared for measurement of sugar in their nectar sugar concentration by pipetting 10mL of distilled water into a sample cup. Cups were then agitated by hand for sixty seconds. Samples were then stored for thirty-six hours to ensure all nectar was washed out of the flower samples and dissolved into the water. A pipette was used to collect 1mL sub-samples from each washed sample cup. Sugar content from each sub-sample was then measured using a Milwaukee MA971 electronic refractometer. Brix values were recorded for each plant, for each collection period. Collected bees were identified to genus by using a guide provided by Dr. Mike Arduser, a recognized bee expert, the book backyard bees, and the Bumble Boosters guide to Nebraska Bumble bees. Additionally, representative samples for each collected species were mailed to Dr. Mike Arduser for validation of identification. Bee specimens were pinned, labeled with their respected genus or species, if applicable. Various native bees have yet to be described to species.

Data Analysis. Data were analyzed to determine any statistical significance in the average abundance and diversity of bees per observation between each plant pairing. Abundance was measured as the average number of specimens collected per observation. Diversity, or richness, was measured by the average number of distinct genera collected per observation. Statistical analysis was carried out using R statistical software. Due to many observations resulting in zero abundance and diversity of bees, count models with a negative binomial distribution were used to determine statistical significance within a 95% confidence interval. Negative bionomial count models were used to determine if the ratios of any of the counts were different than one, rather than zero. Measured plant attributes, height, spread, flower count, and sugar content of nectar (Brix) were compared to abundance and diversity of bees to find any correlations using a Spearman's Rho. This model was used to account for skewness within the data. The r^2 obtained from the analyses were then used to determine the strength of the correlation, where 0.00 - 0.19, 0.20 - 0.33, and 0.34 - 0.67 are described as weak, moderate, and substantial respectively (Chin, 1998).

Data were analyzed for 2016 and 2017 individually, then combined for both years. During the first year of data collection, data were analyzed for the pairings of *Perovskia atriplicifolia* v *Salvia azurea* and Aster X*dumosus* v *Symphyotrichum novae-angliae*. No statistical analyses were made in for the *Monarda didyma* v *Monarda fistulosa* pairing in 2016. Due to the short amount of time between planting and data collection, *Monarda fistulosa* plants did not reach maturity and bloom until the second year of data collection.

Results

Monarda didyma* v *Monarda fistulosa: 22 bees were collected from the introduced *Monarda didyma* during the study. *Lasioglossum spp.* was the most common genus, followed by *Heraides carinata*, and *Bombus bimaculatus* (Figure 3). *Monarda fistulosa* did not bloom during the first year of data collection, due to immaturity, but 131 bees were collected from it in 2017. *Apis mellifera*, *Heraides carinata*, and, *Bombus bimaculatus* were among the most common bees found on *Monarda fistulosa* (Figure 4). *Monarda fistulosa* had a higher average number of visitors (abundance) per observation than *Monarda didyma* (Table 2). The number of distinct genera per observation (diversity) was higher in *Monarda fistulosa* as well (Table 2).

Perovskia atriplicifolia* v *Salvia azurea: The non-native *Perovskia atriplicifolia* had a total of 317 bees over the two years of the study. Over half the total number of bees collected were *Apis mellifera*, followed by *Bombus impatiens,* and the recently introduced bee species, *Anthidium manicatum* (Figure 5). *Salvia azurea* had 155 total bees collected from it. Over half the bees collected on this plant were *Apis mellifera*, with *Bombus impatiens,* and *Anthidium manicatum* following in order of abundance (Figure 6). Five specimens of the oligolectic species *Tetraloniella cressonia* were collected during the study on *Salvia azurea*. This species feeds only on the floral resources of the plant *Salvia azurea* (Branhagen, 2016). Overall, *Perovskia atriplicifolia* had a significantly higher abundance and diversity of bees compared to *Salvia azurea* (Table 2).

Aster X*dumosus* v *Symphyotrichum novae-angliae:* The introduced Aster X*dumosus* had 63 bees collected from it during the study. *Apis mellifera, Bombus impatiens,* and *Augochlora pura* were the most prevalent species (Figure 7). The native *Symphyotrichum novae-angliae* had 112 collected from it. Similarly, *Apis mellifera, Augochlora pura,* and *Bombus impatiens* were the most common species collected from it (Figure 8). Despite the difference in total number of bees between plants, this pairing had no significant difference in both abundance and diversity of bees collected from them (Table 2).

Plant attributes. The measured plant attributes of height, spread, flower count, and sugar content of nectar (Brix) were analyzed alongside abundance and diversity of bees to determine if a relationship existed. Height, spread, and flower count had a weak to almost moderate relationship to abundance and diversity (Table 3). Sugar content of nectar (Brix) had an especially weak relationship to both abundance and diversity (Table 3). Flower count had the strongest correlation to both abundance and diversity. All attributes increased in the second year, due to plant maturity.

Discussion

Abundance and diversity of bees changed between the two years of data collection. Both abundance and diversity were found to be higher in nearly every plant during the second year. This difference between years may be due to the change in plant height, spread, and flower count as plants matured, as these attributes were found to be correlated to abundance and diversity of bees.

The managed species of *Apis mellifera* was the most prevalent species in nearly all plants in this study, (except *Monarda didyma)*. Although an introduced species, *Apis mellifera* is an economically important pollinator. Honey bees are essential in the pollination of nearly all agricultural crops that require pollination, making this species one of the most agronomically and economically important insect species in North America (Southwick & Southwick Jr, 1992). Both polylectic and oligolectic species were also attracted to the Nebraska native and non-native species.

Three female and two male specimens of *Tetraloniella cressonia* were collected on *Salvia azurea* during the study. All specimens of this oligolectic bee species were found within the Backyard Farmer test site. Both male and female specimens were able to locate this plant species within a city, separated from any native stands of *Salvia azurea*. *Perovskia atriplicifolia* and Aster X*dumosus* had a noticeably high abundance of *Bombus impatiens* males. Although and introduced species, *Perovskia atriplicifolia* and Aster X*dumosus* provides a great deal of forage for these native bees. The bloom time of these plants coincides with the mating season of this species. These plants can be extremely valuable to male bees needing nutrition during a physically demanding part of their life cycle.

Abundance and diversity varied among plant pairings. The native *Monarda fistulosa* had higher bee abundance and diversity compared to its introduced analogue *Monarda didyma*. In contrast, the introduced *Perovskia atriplicifolia* had a higher abundance and diversity than the native *Salvia azurea*. In comparing *Aster* X*dumosus* and *Symphyotrichum novae-angliae,* there was no significant difference in abundance or diversity of bees attracted to these plants. These results indicate that the attribute of native is not the only or most important factor determining the abundance and diversity of bees attracted to these plants. Other factors likely influence a plant's value as forage for bees, such as individual plant attributes. Due to the weak correlations found between the measured plant attributes and the abundance and diversity of bees, it could be suggested that these attributes may have a greater influence on a plant's value as forage. There was an increase in bee abundance and diversity after the first year. This may be attributed to the increase in all measured plant attributes as the plants matured. Further research to understand how various plant attributes influence a plant's value as forage can possibly aid in the implementation of successful bee conservation project.

While this study yielded interesting results, there are limitations due to its design and unpredicted events. There are ways in which the study can be improved upon. Wild type species could have been used in this study. Due to the lack of availability of straight species, cultivars were used. Cultivars, which are often bred for traits desired by humans (i.e. bloom color, size, and growth habit), may also be impacted in their ability to provide adequate forage for bees. The measurement of sugar in flower nectar was unreliable. Nectar volume was too low to get comparable readings between plant pairings. Currently, there is no reliable method for storing and measuring flower nectar from flower specimens with low nectar volumes (Morrant, Schumann, & Petit, 2009). Analyzing flower nectar qualities may be helpful in further understanding plant qualities that impact their attractiveness to bees though empirical evidence. Landscape qualities among sites were not recorded, due to various limitations. Comparing surrounding landscape qualities among test sites could have helped in the understanding of all the variables that may impact the bees' foraging preferences.

Many pollinator plant "lists" are based upon personal observations, without empirical evidence (Garbuzov & Ratnieks, 2014). Future studies can be tailored to specific ecoregions with their associated plant species to help in designing bee foraging habitats globally. Future studies should focus on the plant and landscape attributes that impact bee abundance and diversity. Weak correlations were found among various plant attributes, but more variables could be recorded and compared in future studies to fully understand the landscape dynamics that impact an area's carrying capacity for bees.

This study was unique in its comparisons of individual plant species and the impact their native origin has on surrounding bees. Our results lead us to suggest using a diverse palette of plant species when creating habitats for bee conservation, regardless of the native vs. non-native status of each plant species. To prevent homogenization of bee communities, we suggest providing the plants needed for oligolectic bee species, such as using *Salvia azurea* for supporting *Tetraloniella cressonia).* Cities and suburbs are underutilized for pollinator conservation. Using these areas to their full potential, through targeted design and management of pollinator habitat, can help maintain healthy ecosystems and worldwide agricultural production.

Tables and Figures

Table 1. Plant Species Used, Family of Plant Species, Origin of Plant Species, Bloom Color of Plant Species and Blooming Period of Plant Species.

Plant	Family	Origin	Bloom Color	Bloom Period
Wild Bergamont (*Monarda fistulosa*)	*Lamiaceae*	Native: Central United States	Pink	July to September
Bee Balm (*Monarda didyma*)	*Lamiaceae*	Non-Native: Eastern United States	Pink	July to August
Pitcher Sage (*Salvia azurea*)	*Lamiaceae*	Native: Central United States	Blue	July to October
Russian Sage (*Perovskia atriplicifolia*)	*Lamiaceae*	Non-Native: Eurasia, Himalayas to Western China	Lavender/Blue	July to October
New England Aster (*Symphyotrichum novae-angliae ‘Purple Dome’*)	*Asteraceae*	Native: Central to Eastern United States	Purple	September to October
Wood’s Aster (Aster X*dumosus ‘Woods Purple’*)	*Asteraceae*	Non-Native: Eastern United States	Purple	September

Table 2. 2016/2017 Abundance and Diversity

	Abundance		**Diversity**	
Plant Species	$\bar{x}$	p	$\bar{x}$	p
Monarda didyma	0.2738	0.0001	0.2143	0.0001
Monarda fistulosa	2.0154		1.2615	
Perovskia atriplicifolia	2.5691	0.0018	1.0976	0.0129
Salvia azurea	1.4857		0.7717	
Aster X*dumosus*	1.2857	0.6268	0.6939	0.9112
Symphyotrichum novae-angliae	1.1212		0.6768	

Table 3. R^2 Values of plant attributes against abundance and diversity

	Abundance	Diversity
Height	0.2025	0.1681
Spread	0.2401	0.1849
Flower Count	0.2809	0.2209
Brix	0.0004	0.0036

Figure 1. Map of test sites

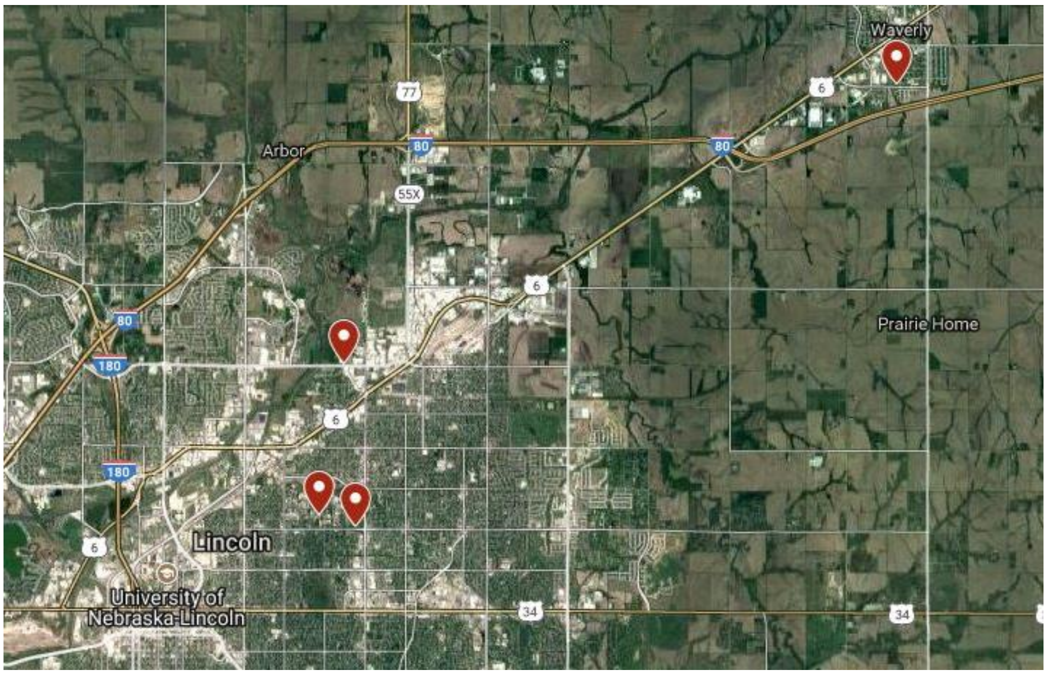


Figure 2. Backyard Farmer Garden Plot (2016)

Figure 3. Bee species and gender collected from *Monarda didyma* (2016 & 2017)

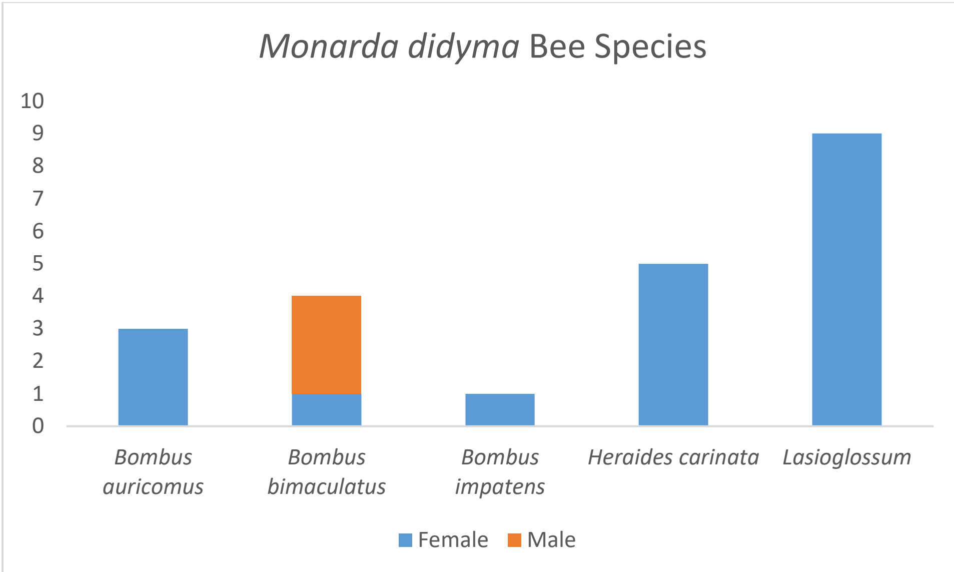


Figure 4. Bee species and gender collected from *Monarda fistulosa* (2016 & 2017)

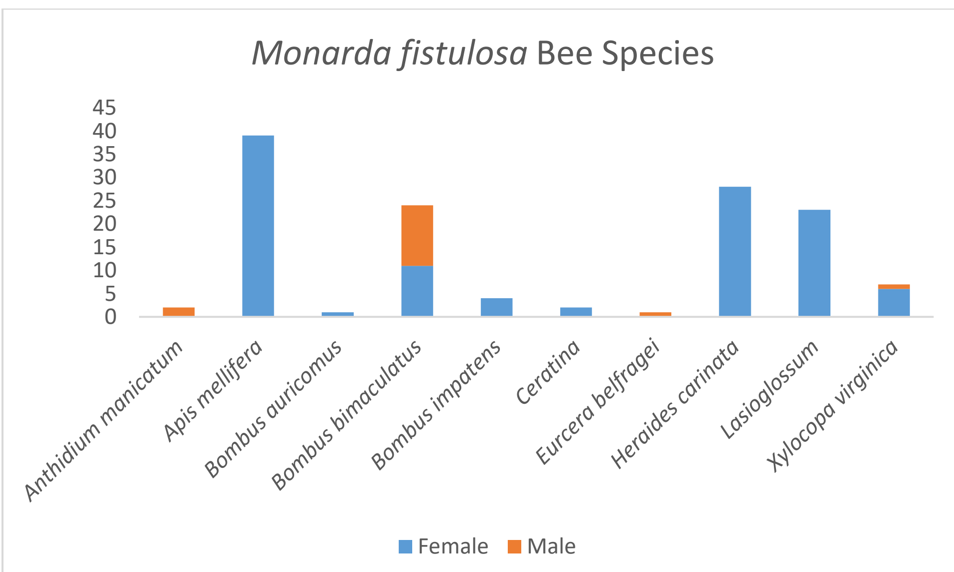


Figure 5. Bee species and gender collected from *Perovskia atriplicifolia* (2016 & 2017)

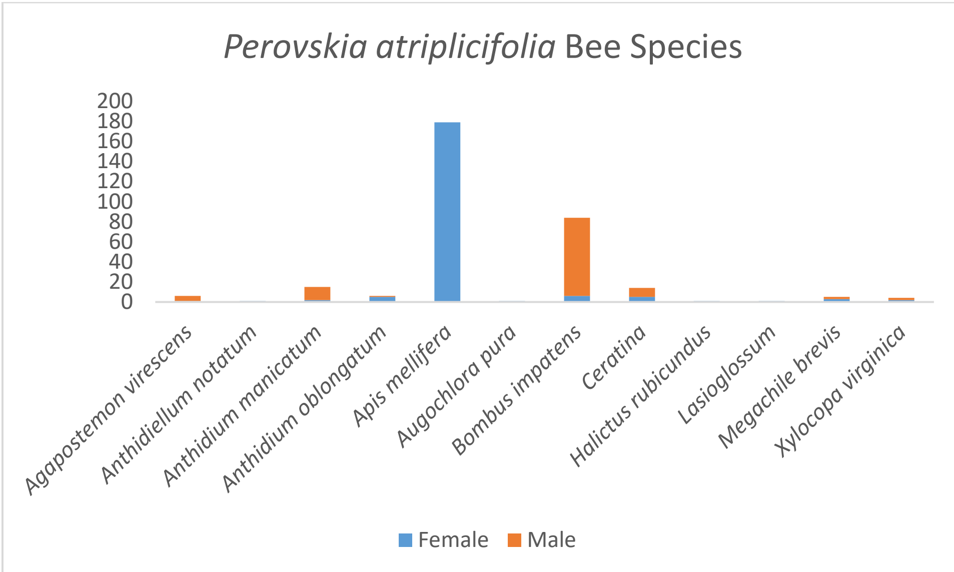


Figure 6. Bee species and gender collected from *Salvia azurea*. (2016 & 2017)

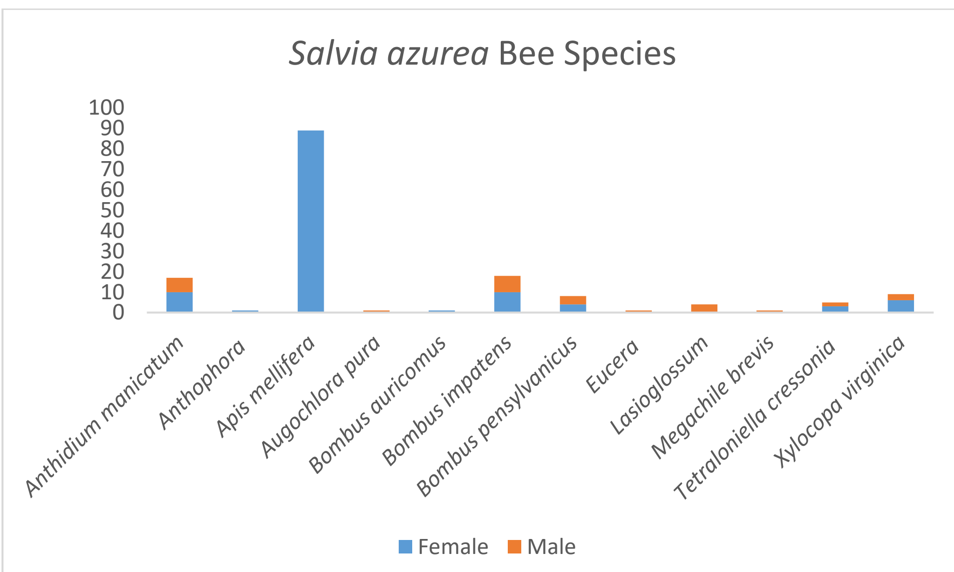


Figure 7. Bee species and gender collected from Aster X*dumosus* (2016 & 2017)

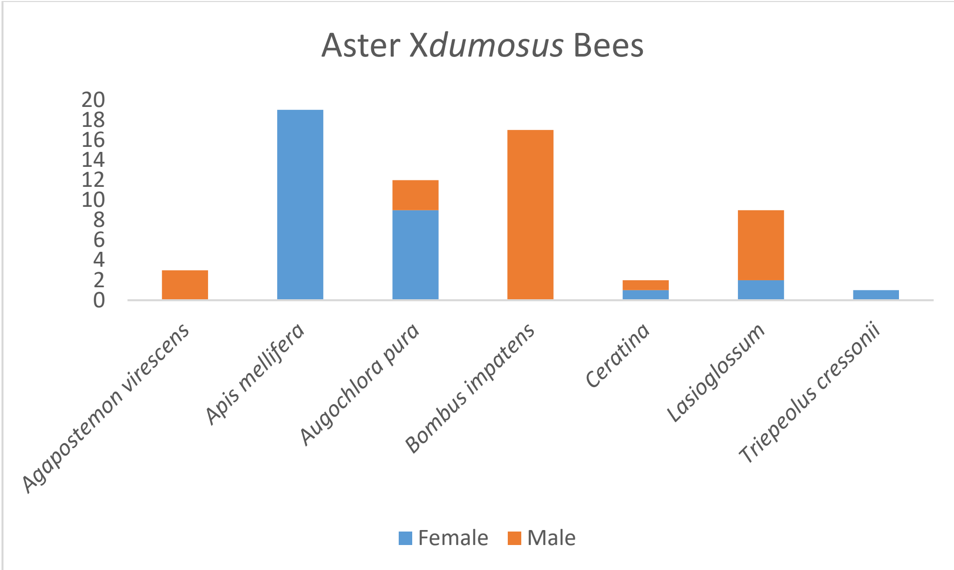
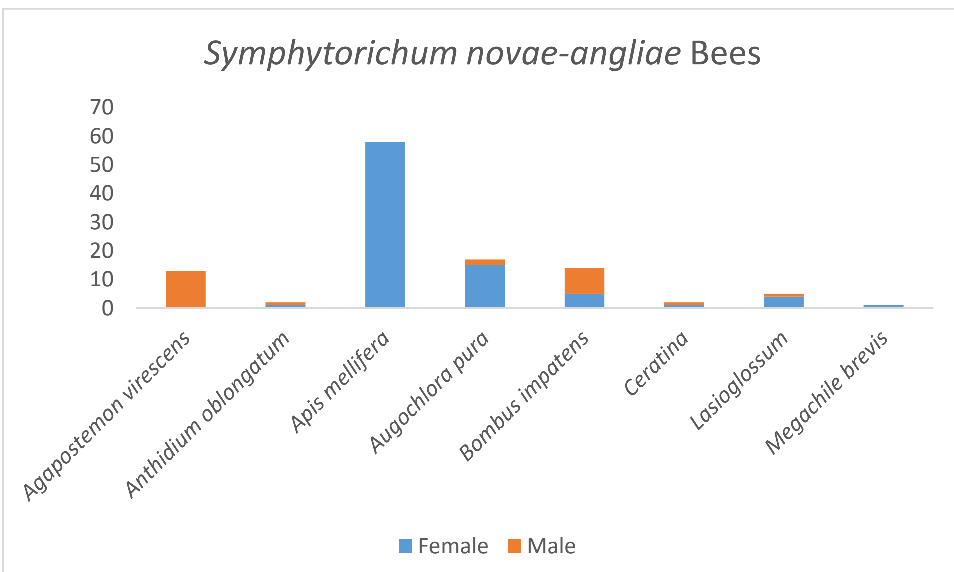


Figure 8. Bee species and gender collected from *Symphytorichum novae-angliae* (2016 & 2017)



Chapter 2. Pollination Conservation Knowledge and Pollinator Plant Recommendations: Practices of Horticulture Retail Sales and Design Professionals

Abstract.

Pollinating insects are integral to the health of all terrestrial ecosystems and worldwide agriculture. Urbanization has greatly influenced this loss of nutritional resources and habitat. This can be reconciled through targeted landscape practices, such as providing nectar- and pollen- rich plants and managing pollinator habitat in urban areas, like home landscapes. As homeowners attempt to conserve pollinators through horticultural practices, they seek the advice and guidance of garden center employees. The knowledge retail employees have about pollinators and the recommendations they are giving customers on the subject is unknown. Here, a nationwide survey was developed and distributed to gauge current knowledge levels of horticulture retail employees about pollinator science and conservation practices. Our findings suggest overall knowledge level and recommendations are fairly good, but room for improvement exists in specific groups of retail employees. Specifically, employees without any type of horticultural certification and part time employees should be the focus on educational outreach efforts.

Introduction.

In recent years, much public attention has been focused on pollinating insects, the facilitators of the majority of plant species. Part of this attention is due to honey bee colony collapse disorder. Since 2006, beekeepers have been reporting an average annual winter loss of 30% of their hives (Kulhanek et al., 2017). In addition, other charismatic insect pollinators, like monarch butterfly populations, have been declining since the mid-1990s (Brower et al., 2012). In early 2017, the rusty patched bumblebee (*Bombus affinis*) was placed on the endangered species list--the first species of bee in the lower forty-eight states. In June of 2014, President Obama issued a memorandum that established a task force focused on pollinator health to create a nation-wide strategy to conserve the nation's honeybees and other pollinators (WhiteHouse, 2014). This memorandum led to the creation of the Pollinator Health Task Force, an inter-departmental task force including members from thirteen different governmental agencies.

Public concern about pollinator decline and the resulting detrimental impacts is warranted. Animal mitigated pollination is responsible for the reproduction of 87.5% of the world's terrestrial plant species (Ollerton et al., 2011). 35% of all agronomic crops fall into that percentage (Klein et al., 2007). The monetary value of pollination is estimated to be $18-$27 billion annually in the United States alone (Mader et al., 2011). Pollination as an ecological service is necessary for maintaining ecosystem health and for ensuring food security. Thus, it is imperative that pollinators are protected and their health supported through scientific research and conservation practices.

The decline of pollinating insects is suspected to be a result of multiple factors including changes in climate, parasites, disease, and pesticide interactions (Goulson et al., 2015). In many cases, it is a combination of all listed factors. However, the greatest contributing factor is thought to be habitat and forage loss (Goulson et al., 2015; Kerr et al., 2015; Vanbergen & Initiative, 2013). This habitat and forage loss is a result of increased land use intensification through urbanization. In urbanized areas, the floral resources that these beneficial insects need for food and habitat are low in abundance, low in diversity, and greatly separated.

However, there is hope in the case of urbanization. Numerous studies have found that when appropriate floral resources are present, urban areas have the capacity to support healthy pollinator populations (Ahrné et al., 2009; Baldock et al., 2015; Banaszak-Cibicka & Żmihorski, 2012; Davis et al., 2017; Eremeeva & Sushchev, 2005; Fortel et al., 2014; Frankie et al., 2009; Geslin et al., 2015; Gunnarsson & Federsel, 2014; Jha & Kremen, 2013; Lowenstein et al., 2015; Lowenstein et al., 2014; Persson et al., 2015; Potter & LeBuhn, 2015; Sirohi et al., 2015; Threlfall et al., 2015; Tommasi et al., 2012; Williams & Winfree, 2013; Wojcik et al., 2008; Wray & Elle, 2015). Due to the relatively small functional requirements, habitat range, short life cycle, and nesting behavior of pollinators, urban areas can be suitable areas devoted to their conservation (Hall et al., 2017). Despite numerous factors that would make urban areas unsuitable for pollinators, like lack of exposed ground due to concrete, the presence of diverse floral resources have been found to overcome many of these factors (Hülsmann, von Wehrden, Klein, & Leonhardt, 2015).

Urbanization is happening. North America has the highest amount of residents living in cites, with 82% of the population living in urban areas (Nations, 2014). Nearly one quarter of the United States land area consists of land that could potentially be put to use in conserving pollinators (Bigelow & Borchers, 2017). These urban, suburban and rural areas consist of parks, schools, businesses, but are mostly comprised of privately owned property, with yards. The vast majority of this land is underutilized, and with targeted landscape practices, these lands can be used for conservation. Homeowners are willing to have their landscapes take on an ecological role. A study found a majority of homeowners are willing to have ecologically beneficial landscapes, including planting native plants (Helfand et al., 2006).

Pollinator conservation in the home landscape may be a challenge for homeowners, due to the complexities of knowing which plants are beneficial to pollinators, how to design landscape features beneficial to pollinators, how to manage pollinator habitat, and how to reduce chemical inputs. Expecting homeowners to have the knowledge and skills necessary to design and manage pollinator habitat is unrealistic, as it is not common knowledge. Indeed, a 2017 survey of college science majors found there to be deficiencies in knowledge of both pollinator structures, as well as conservation practices (Golick et al., 2017). A combined lack of knowledge of pollinators, landscaping, and landscape practices to sustain pollinator habitat is a barrier to implementing sound pollinator conservation practices.

Homeowners use many convenient resources, such as websites, books and workshops to educate themselves on various landscape topics and pollinator conservation. Among those convenient resources are online plant lists that recommend plants for pollinator habitats. Although many of these resources give helpful recommendations, they are based primarily upon personal observations, and lack any empirical evidence to support their claims (Garbuzov & Ratnieks, 2014). The most common source for landscape information often comes from the point of sale of their landscape materials (Meyer & Foord, 2008). This leaves horticulture retail stores and their employees at the forefront of education on this the subject of pollinator conservation and landscaping.

Staff subject knowledge on subjects like plant recommendations and landscape practices is a concern for garden center customers (Barton et al., 1998; Safley & Wohlgenant, 1995). A 2007 study of Connecticut horticulturalists found that there were some gaps in knowledge of invasive plant species within the nursery trade, whereas less than 15% of respondents believed Japanese silver grass (*Miscanthus sinensis*) and butterfly bush (*Buddleja davidii*) were invasive, when in fact both are (Gagliardi & Brand, 2007). Although unrelated to pollinator conservation, this shows that there may be some knowledge gaps in plant selection in the horticulture industry. Plant selection is integral to pollinator conservation, as not all plants provide adequate forage for pollinators, and current recommendations may not be wholly accurate.

Public interest in pollinator conservation has increased markedly in the past decade (Joseph S. Wilson et al., 2017). If this trend is to continue, the number of homeowners seeking assistance in pollinator conservation should be expected to rise as well. Horticultural retailers' primary concern is to meet the needs of their customers. How well equipped these professionals are in meeting the specific needs of a customer wanted to use their landscape for pollinator conservation is unknown. Due to the importance of pollinators and the need for their conservation, it is important to ensure the information homeowners are given from retailers is accurate. In order to gauge retailer knowledge, a nationwide survey of horticulture retail employees was developed and conducted. The objectives of this survey were to 1) discover what plant and management recommendations employees were giving customers pertaining to pollinator conservation

2) assess employee knowledge on pollinators and pollination biology and 3) determine where to focus possible education and outreach as well as which subjects to focus said educational programs on.

Methodology

A survey was developed to determine what plant species were being recommended to customers to attract pollinators, what landscape practices were being recommended to conserve pollinators, and how knowledgeable employees were about pollination systems. An online survey and script of follow-up interview questions was developed by faculty in the departments of Agronomy/Horticulture and Entomology at the University of Nebraska-Lincoln in the winter of 2016. Following its development, it was sent to be reviewed by an Institutional Review Board (IRB) to assure the safety and privacy of the respondents during the study. After approval, the survey was hosted online via Qualtrics.

The survey participants were identified through multiple approaches. Email contacts were purchased from Exact Data Inc. of Chicago, Illinois. The contacts were determined to be part of the survey population via the four-digit Standard Industrial Classification (SIC) codes. Respondents were found through the SIC codes tied to industries related to horticulture retail and other horticulture-related industries. The state horticulture and landscape associations of California, Texas, Iowa, New York, Minnesota, Oregon, and Nebraska; the Association of Professional Landscape Designers (APLD); American Horticulturalists Association; Florida Association of Native Nurseries; the Nebraska Statewide Arboretum; Nebraska Turf Association and Western Nursery and Landscape Association (WNLA) were contacted and asked to share a link to the survey through their respected social media outlets and newsletters. In addition, a contact list of individuals with herbicide application certification in Nebraska was used, as many retailers hold this certificate. This survey was available for an estimated 7,500 + individuals. In an attempt to increase participation, two reminder emails were sent and participants were given a chance to win a $25 Amazon gift card. The survey was made available from February 28, 2017 to April 24, 2017.

The survey contained 22 questions, comprised of a combination of open- and close-ended, and rank-order questions (Table 1). Distraction questions were used to eliminate non-target respondents and falsified survey responses. The final question asked respondents to volunteer for a short recorded phone interview.

The scoring of responses were based on the pollination framework metrics used in (Golick et al., 2017) (Table 2). Responses to questions were scored based upon perceived correctness by authors Golick and Westerhold separately, then later reconciled for a final score for each respondent. Respondents with higher scores were said to be more knowledgeable about pollinator biology and gave "better" or more correct suggestions on landscaping practices. Questions 14, 15, 16, and 17 were all scored. All scores were then totaled to give each respondent a total knowledge score. The highest possible total knowledge score was 14, and the lowest possible score was 0.

Using R statistical software, total knowledge scores were compared among demographic responses. Depending upon the number of possible responses in each demographic question, a t-test or analysis of variance (ANOVA), both with 95% confidence, was employed. Demographic variables including time spent with customers, years of experience, job title, age, gender, education, certification, store type, store operating season, and location were all compared. In the rank-order question, the mean scores of each plant attribute was calculated to determine what respondents found most to least important. A Mann-Whitney test with 95% confidence was performed using SPSS statistical software to determine any differences in ranking between demographics.

Phone interviews were used to gather more detailed information on respondents' survey responses. The interview discussions were semi-structured, guided by questions (see Figure 1) with additional prompts for elaboration of answers where appropriate. Interviews were recorded, transcribed and analyzed by primary investigators Golick and Westerhold to determine if any themes derived from commonalities existed among interviewee responses.

Results

Initial Results. The survey had 224 respondents. Of those, 114 respondents completed all questions, and properly answered the distractor question responses. Descriptive statistics were used to conceptualize scores earned by respondents on each scored question as well as the total scores (Table 3).

Demographics. Of the 114 respondents, 50 were female and 64 were male. 55-64 was the most prevalent age group (36%), followed by 45-54 (21%), and 35-44 (17%). The majority of respondents (73%) were college educated, stating they had a degree past a high school diploma. Respondents' job titles were primarily business owners (26%), landscape designers (23%), and sales associates (20%). Over half the respondents (59%) worked at local horticultural retailer businesses while "other" was the next most common response (30%); consisting of groundskeepers, designers, and governmental/non-profit employees. These various types of workers were mostly certified in their field, with (61%) reporting some sort of horticultural certification in their state. Few of the respondents sold plants all year long. Only (27%) of respondents said their businesses were open all year.

Pollinator Knowledge. In the first pollinator knowledge question, "Which of the insect choices below are considered important plant pollinators?" the highest possible knowledge score was five. Respondents scored high, with the mean score among respondents being 3.63, with a standard deviation of 1.21.

For the following question, "How do insects benefit from pollinating plants?" open response answers were provided by participants. Out of a possible knowledge score of three, the mean knowledge score was 2.44 with a standard deviation of 0.59. The benefits of food represented 35% of the responses. Nectar and pollen were mentioned specifically in these answers. Nectar was mentioned (15%) of the time while pollen was rarely mentioned (5%). Benefits apart from "food" were plant reproduction to create more forage resources (plants) (15%), insect reproduction (11%), and habitat (11%).

Plant and Management Recommendations. A total of 203 landscape recommendations were provided after respondents were prompted to "Please provide 3-5 landscape management practices you would recommend to customers who wish to conserve pollinators." Providing plants for pollinators was the recommendation most frequently given response (22%), followed by careful use of chemicals (18%), and create/leave habitat (14%), no chemicals (12%), and reducing outside inputs (12%).

When asked to “Name at least 4 plants you believe to be beneficial to pollinators,” the most popular plant groups mentioned were milkweeds (*Asclepias*) (14%), coneflowers (*Echinacea*) (8%), asters (Aster) (5%), and butterfly bush (*Buddleia*) (5%). Other popular responses (>1%) included *Monarda, Liatris, Salvia, Sedum, Ruta, Solidago, Trollium, Nepeta, Rudbeckia, Achillea, Baptisia, Eupatorium, Perovskia, Helianthus, Malus, Penstemon*, *Pycnanthemum, and Prunus*). The types of plants listed were forbs (63%), shrubs (22%), trees (10%) and grasses (4%). Over one-third of all plants listed (39.7%), were known host plants for various species of Lepidoptera larvae.

Following plant recommendations, respondents were also asked, “Which of the choices below best describe why you chose the plants you did in the previous question?” Most respondents (91%) cited that they knew which plants were good for pollinators based upon personal observation. Additional knowledge of beneficial pollinator plants included academic or industry research (52%); reading an article about the plant in a trade magazine, online, or elsewhere (40%); and then hearing from others that the plant was good for pollinators (31%). In the next question, respondents were asked, “Are you more likely to recommend a native plant than non-native plant, where these plants otherwise have all of the same growing requirements and attraction to pollinators?” Over half of respondents (62%) chose yes, which suggests that these retailers may consider native plants more beneficial for pollinators.

Rank Order of Important Plant Attributes for Pollinators. In a ranked order type question, respondents were asked, “When recommending plants to a customer who is interested in attracting pollinators, how would you rate the importance of the following plant attributes? (1) being most important and (10) being least important.” Based on mean ranking, respondents ranked the plant attributes in the following order: (1) the plant's attractiveness to pollinators, (2) the bloom period of the plant, (3) the plant's origin (Is it native or introduced?), (4) the plant's sun and water requirements, (5) the bloom color of the plant (6), the lifespan of the plant (Is it a perennial or an annual?), (7) the size of the plant (8), the specific selection/cultivar of the plant (9), the presence of plant protective pesticides on the plant, and (10) the plant’s price (Table 4). The Mann-Whitney test found two attributes were ranked significantly different among one demographic variable. Respondents with certifications ranked "attractiveness to pollinators” higher than those without certification (p=0.41). Certified employees ranked this attribute highest (1) whereas non-certified respondents ranked it nearly last (9).

Pollinator Knowledge among Demographics. Significantly different scores existed in three variables: 1) gender, 2) certification, and 3) store operating season. Female respondents had a statistically significant higher mean total knowledge score (9.06) compared to male respondents (7.83) (p=0.037). Respondents with some sort of certification had a higher mean total knowledge score (9.04) than those without certification (7.33) (p=0.005). Respondents who reported to work at a store that was open all year had a higher average score (9.94) than those who worked at stores open for only part of the year (8.20) or just for a season (7.60) (p=0.003). No significant difference in knowledge score existed among time spent with customers, years of experience, job title, age, education, store type, and location.

Customer Advice and Questions. In order to understand what kind of questions customers were asking at garden centers, respondents were asked to "List up to 3 common questions customers ask you about pollinators and/or pollinator plants." The questions that customers asked employees most were: "What plants are best for pollinators?" (21%), questions about general plant attributes/requirements (18%) and "How do I attract specifically butterflies?" (14%), "Will X chemical hurt the bees/butterflies?" (7%), "Will this attract bees? I don't want to get stung by bees." (6%), "What landscape practices will help pollinators?" (5%), "Does this plant have neonicotinoids?" (5%), and "Do native plants attract more pollinators?" (5%)

Interviews. Seven respondents volunteered for phone interviews. These volunteers varied in their backgrounds and their occupations. However, many of the responses they gave were very similar.

The first question asked during the interview was, "When you completed the survey, you listed 4 plants as choices as good pollinator plants. Can you tell me a little about why you chose these plants?" Consistent with the initial survey, personal observation was the most common response. For example, a volunteer said, "Well, partially it's based on observations, I've been here for ages for my whole life I've watched and enjoyed (insects) as a kid. So most of my information is based on personal experiences."

As for the next question, "Can you tell me how you have learned what you know about pollinators and conservation?" volunteers almost unanimously said that it was based upon their own personal experiences. One volunteer gave a specific information source, saying, “The Xerces Society, also the State University. [The University] has some really nice little booklets about pollinators in our area they give out for free.’

In response to, “What do you believe are the biggest challenges in planting/designing landscapes for pollinators?” every volunteer mentioned lack of knowledge on the part of their customers. For example, one volunteer said, "So I think that it has to be about education and you have to educate them (the public) in a way that makes them want more. You can't beat them with it.”

Every volunteer said they shared their knowledge of pollinators with co-workers as well as other individuals in their lives. Volunteers said they share knowledge both formally and informally and use social media to spread pollinator knowledge. One volunteer said, "I do (share knowledge) on a regular basis. None of my information is exclusively private. We live in a very free world, people can Google anything they want. So you may as well share your information and that makes you a, I don’t want to say an expert, but a knowledgeable individual in the field. People come back to me to design for them and find information. I consider that very valuable. I share on social media, I share on my website, and I tweet a lot so any and all those sources are frequently used."

When asked, “In your experiences working with customers, what are their major concerns when choosing plants in their landscapes? there was no surprise regarding the responses that were given. [Customer’s concerns are] "That the plants are going to look good; that they are going to last, meaning they are not going to die; that they are going to appeal to the clients, and their friends, and family; and they’re going to be low maintenance, low maintenance for you know trimming, deadheading, and maintenance.”

This quote was an accurate example of responses as performance of plants in terms of hardiness and appearance were the two common ideas expressed by all volunteers.

When asked, “Do you have a gardening philosophy?” the majority of volunteers said yes, but did not have a prepared answer. One respondent did have a prepared gardening philosophy stating to “Garden for life.” In the following question, “Do you think the business you work for cares about pollinators?” all volunteers replied “Yes,” but were unable to provide specific examples of how their respected businesses express a concern for pollinators. In our final question, “Are the plants your business sell labeled as being beneficial for pollinators? (i.e. food, habitat etc.)”, only one volunteer said their business labeled their plants for pollinators, describing that the plant labels for pollinator plants had “a small butterfly on it.”

Discussion

Survey results supported suggest that most employees have some knowledge about pollinators, pollinator biology, and plant/landscape recommendations for pollinators. Additional strengths among respondents were in knowing what insect groups were known pollinators, and understanding the mutual benefits of pollination and what landscape practices were best for conserving pollinators.

Knowledge of beneficial plants for pollinators was the weakest subject, having the lowest mean knowledge score (M=1.82). Plant recommendations included limited bloom times (only summer) and low diversity of plant types (forbs, tree, shrub, grass). Early spring and late fall blooming plants are crucial for pollinator health (Mader et al., 2011). Tree and shrub species were not well represented by respondents. Trees and shrubs are some of the earliest and latest blooming forage plants for bees, and are forage plants for generalist and solitary bees (MacIvor, Cabral, & Packer, 2014). Clearly, there is a need to educate retailers about the importance of early and late blooming plants as well as the importance of trees and shrubs in pollinator habitats.

Respondents without certification had a significantly lower total knowledge score (M = 7.33) on the scored survey questions than their counterparts with certifications (M = 9.04) (p=0.005). This was also true for respondents who worked at year around businesses (M = 9.94) as compared to seasonal (M = 7.60) (p =0.003) and part-time business (M = 8.20) (p =0.099). If pollinator protection is a topic of importance to a retail business due to increased interest from customers, perhaps certification should be considered for their employees. It can be assumed that certification is an investment of time and money. This investment may not be considered worthwhile for companies for seasonal and part-time employees. In cases where certification is not feasible, our suggestion is to encourage more knowledgeable or certified employees to reach out to their peers and share their knowledge. As for seasonal and part-time retailers who may not be comfortable or simply unsure of questions from customers about pollinators, we recommend labeling beneficial plants as well as giving these businesses access to high-quality educational materials to distribute to customers. This is a great opportunity for local extension agencies, non-profits, government agencies, and private industries to develop outreach materials or programs.

Horticulture retail staff also rated the importance of the presence of plant protective chemicals (pesticides) as 9th in important plant attributes. This is a concern, as pesticides can pose a risk to pollinator health. A recent survey found that nearly 70% of garden center plants sold to the public were found to contain neonicotinoid pesticides (Lentola et al., 2017). Neonicotinoid pesticides have been implicated by some studies as one of the causes of pollinator declines (Goulson, 2013; Rundlöf et al., 2015; Van der Sluijs et al., 2013; Whitehorn, O'Connor, Wackers, & Goulson, 2012). While the risk of neonicotinoids and other pesticides found on retail sales plants is not fully understood, it is safe to assume customers are concerned with pesticides being present on new plants, especially those planted for the purpose of providing forage to pollinators. Raising employee awareness about the presence of pesticides can be helpful in making customers aware of possible risks of exposing pollinators to potential pesticides.

Based on survey data, we recommend educational materials to focus on plant selection, management practices, and a list of pollinators. Although many employees understood which major insect groups were responsible for pollination, there is a lack of knowledge about the importance of bees as a group, with most respondents being focused on butterfly conservation. Responses showed a higher interest in conserving butterflies than bees, despite bees being more efficient pollinators (Mader et al., 2011). As for diversity of pollinators, a 2017 survey states that only (14%) of their respondents were able to guess the number of bee species in the United States to the nearest 1000, despite (99%) believing bees to be critical or important (Joseph S. Wilson et al., 2017)

Conclusion. This survey was the first of its kind in respect to the subject of pollinator conservation. There is more that could be done to increase learning of this subject. As with many surveys, a larger number of respondents can be contacted to increase both accuracy and precision of determine the scope and distribution of potential educational materials. Understanding the wants and needs of customers could help understand what needs to be done to improve knowledge and outreach. It is also unknown what retailers are doing to ensure the information and recommendations they are giving their customers is actually being used. This would be another way to expand upon the knowledge gained from this study.

This survey provides some understanding regarding what retailers know about pollinators, and what they are telling their customers. These retail employees are in a position that can greatly influence pollinator conservation, by educating homeowners and equipping them with the right materials and information to create ecologically beneficial landscapes. In this study, we identified some deficiencies horticultural retailers have in pollinator knowledge among horticultural retailers, and which specific groups of retailers would benefit most from educational efforts. Horticultural professionals are important stakeholders in pollinator conservation. Our hope is that the results of this study can be used to better educate and equip horticultural retail sales people with effective pollinator conservation information and strategies.

Tables & Figures

Table 1. Survey questions with possible response(s), sorted by question category.

	Demographic Questions
Q2 On a typical day, what percentage of your time is devoted to working directly with customers? (e.g. answering horticulture questions & making plant recommendations) **Condition:** 0% Is Selected. Skip To: End of Survey.	0% 1-20% 21-40% 41-60% 61-80% 81-100%
Q3 How long have you worked in a horticultural related profession? (Working with plants) **Condition:** 0 years Is Selected. Skip To: End of Survey.	0 years less than a year 1-5 years 6-10 years 11-15 years 16-20 years 21-30 years 31 or more years
Q4 Select the title(s) that best represents your role at your place of employment (where you help customers make plant recommendations).	Sales associate and/or Customer Service Cashier Manager Florist Nursery/Greenhouse Worker Business Owner Plant Propagation and Breeding Landscape designer Other (please describe) ______
Q5 What is your age as of today?	19 - 24 25 - 34 35 - 44 45 - 54 55 - 64 65 - 74 75 - or older
Q6 What is your gender?	Male Female Other
Q7 Which of the choices below best describes your level of education?	Less than high school High school graduate Some college 2 year degree

	4 year degree
	Professional degree Doctorate
Q8 Do you have any certifications in the landscaping/nursery industry? (state, regional, or national)	Yes No
Q9 Which of the choices below best describes the business you work for?	A nationwide chain retailer that does NOT specialize in horticulture A nationwide chain retailer that specializes in horticulture A regional chain retailer that does NOT specialize in horticulture A regional chain retailer that specializes in horticulture A local retailer that does NOT specialize in horticulture A local retailer that specializes in horticulture Other ___________________
Q10 How much of the year does the business you work for sell plants?	All year 6 months or more Seasonal
Q11 What state do you work in?	
Pollinator Knowledge Questions	
Q14 Which of the insect choices below are considered important plant pollinators? (check all that apply) **Condition:** Robots Is Selected. All respondent responses discarded	Bees Beetles Butterflies Flies Wasps Cockroaches Robots Mantids
Q15 In your own words, how do insects benefit from pollinating plants? Please provide 1-3 sentences.	
Conservation Recommendations	
Q13 When recommending plants to a customer who is interested in attracting pollinators, how would you rate the importance of the following plant attributes? (1) being most important and (10) being least important (click and drag to reorder selections).	The plant's origin (Is it native or introduced?) The bloom period of the plant The bloom color of the plant The plant's price The size of the plant. The plant's sun and water requirements. The plant's attractiveness to pollinators. The lifespan of the plant. (Is it a perennial or an annual?) The specific selection/cultivar of the plant. The presence of plant protective pesticides on the plant.
Q16 Please provide 3-5 landscape management practices you would recommend to customers who wish to conserve pollinators.	

Q17 In the area provided below, please name at least 4 plants you believe to be beneficial to pollinators (If possible, use the plant's scientific name [including selection/cultivar]).	
Q18 Which of the choices below best describe why you chose the plants you did in the previous question . (Check all that apply)	I have observed these plants to attract pollinators The plant is labeled as a "pollinator plant" I have read academic or industry research that said these were good plants for pollinators. I have read an article in a magazine, online, or elsewhere that they were good pollinator plants. I have personally researched or ran trials to determine the attractiveness of these plants to pollinators. I have heard from other people that they were good pollinator plants. Other ____________________
Q19 Are you more likely to recommend a native plant than non-native plant, where these plants otherwise have all of the same growing requirements and attraction to pollinators.	Yes No Depends, please explain ____________________
Q20 Please list up to 4 questions or concerns you have for recommending plants for impacting pollinator health.	
Customer Advice and Questions	
Q12 Please list up to 3 common questions customers ask you about pollinators and/or pollinator plants.	

Table 2. Pollinator framework knowledge related to pollination biology and conservation

Question	Score	Description	Examples of Responses
Which of the insect choices below are considered important plant pollinators? (check all that apply)	5	Bees, Beetles, Butterflies, Flies, Wasps	"Bees,Beetles,Butterflies,Flies,Wasps"
	4	Bees, Butterflies, 1-3 other correct insects	"Bees,Butterflies,Wasps"
	3	Bees, Butterflies, 1-3 other correct insects, 1 or more incorrect insects	"Bees,Beetles,Butterflies,Flies,Wasps,Mantids"
	2	Bees and Butterflies	"Bees,Butterflies"
	1	Any response, but excludes Bees	"Butterflies,Flies,Wasps"
	0	No correct response	
In your own words, how do insects benefit from pollinating plants? Please provide 1-3 sentences.	3	The respondent demonstrates systems type thinking. The response goes beyond forage and acknowledges long term impacts, such as reproduction of plant species for future food sources.	"Pollinating plants provide habitat for a wide variety of insects, thus increasing biodiversity across a landscape. Pollinating plants provide food for both larval and adult insects and also cover to escape predators."
	2	Response acknowledges pollinating insects receive food while pollinating only.	"Food source"
	1	The respondent gives vague, or incorrect statement.	"They are vital to all living species. We could not survive without them, as all our food is derived from plants."
	0	The respondent give no answer	"We NEED them, even the anoying ones."
Please provide 3-5 landscape management practices you would recommend to customers who wish to conserve pollinators.	3	The response goes beyond providing plants and eliminating chemical inputs. A demonstration of systems thinking is displayed, with all recommendations being considered correct.	"Create habitat for pollinators by leaving areas undisturbed during spring or Fall cleanups. Minimize amount of cutting back in Fall. Do not cut back all groups of perennials, instead leave some groups (rudbeckias, coreopsis, ornamental grasses) to stand for winter interest (and in so doing provides overwintering) Plant select varieties to attract various different pollinators; moths, solitary bees, honeybees"
	2	Two or more recommendations are considered correct, with one being considered contradictory, vague, misleading, or incorrect.	"plant a variety of colors, plants, etc. the more alive the garden is with different species the more pollinators will visit."
	1	Only one or two recommendations are considered correct, with others being considered contradictory, vague, misleading, or incorrect.	"DON'T SPRAY FOR BROADLEAF WEEDS!!!! no insecticides either."
	0	No recommendations were considered correct.	
In the area provided below, please name at least 4 plants you	3	All plants listed are known nectar and pollen sources for pollinating	"Chokecherry (Prunus virgiana), Purple Coneflower (Echinacea purpurea), Flowering Crabapple/Apple

believe to be beneficial to pollinators (If possible, use the plant's scientific name [including selection/cultivar]).		insects, or larval host plant. 2 or more plants provide resources at crucial times of year (early spring and/or late fall)	(Malus sp.), Common Milkweed (Aesclepias syriacus)”
	2	All plants listed are known nectar and pollen sources for pollinating insects, or larval host plant	“Asclepias, Echinacea, Liatris, Monarda”
	1	Most plants are known nectar and pollen sources. Semi-diverse, and semi-diverse bloom periods	“succulants, hosta, butterfly bush, coneflower"
	0	None of the plants listed were considered beneficial for pollinating insects.	

Table 3. Descriptive statistics of scored questions Potential Follow-Up Interview Questions

	Question	n	Mean	st.d
14	Which of the insect choices below are considered important plant pollinators? (check all that apply)	114	3.63	1.21
15	In your own words, how do insects benefit from pollinating plants? Please provide 1-3 sentences.	84	2.44	0.59
16	Please provide 3-5 landscape management practices you would recommend to customers who wish to conserve pollinators.	82	2.17	0.68
17	In the area provided below, please name at least 4 plants you believe to be beneficial to pollinators (If possible, use the plant's scientific name [including selection/cultivar]).	86	1.82	0.62
	Total Score	114	8.37	3.23

Table 4. Plant attribute rank order results

Attribute	Mean Rank
The plant's attractiveness to pollinators.	3.570175
The bloom period of the plant	3.929825
The plant's origin (Is it native or introduced?)	4.149123
The plant's sun and water requirements.	4.517544
The bloom color of the plant	5.017544
The lifespan of the plant. (Is it a perennial or an annual?)	5.77193
The size of the plant.	6.070175
The specific selection/cultivar of the plant.	6.964912
The presence of plant protective pesticides on the plant.	7.5
The plant's price	7.508772

Figure 1. Script used for phone interviews

1. When you completed the survey, you listed 4 plants as choices as good pollinator plants. Can you tell me a little about why you chose these plants?
2. Can you tell me how you have learned what you know about pollinators and conservation?
3. What do you believe are the biggest challenges in planting/designing landscapes for pollinators?
4. Do you educate other employees about plants that are beneficial for pollinators?
    a. If so, through what means/how?
5. In your experiences of working with customers, what are their major concerns when choosing plants in their landscapes?
    a. (If they do not mention pollinators) Do you think pollinator conservation plays a role in plant purchases?
        i. How so?
6. Do you have a landscaping or gardening philosophy?
    a. If so, how do you think this affects your interactions with customers?
7. Do you think the business you work for cares about pollinators?
    a. If so, how does that shown in the business?
8. Are the plants your business sell labelled as being beneficial for pollinators? (I.e. food, habitat etc.)
    a. If so, what information/what does the label look like? Could you describe a typical label?

Official Approval Letter for IRB project #16732 - New Project Form

February 17, 2017

Carter Westerhold

Department of Agronomy and Horticulture

5021 Vine St Apt 707 Lincoln, NE 68504-3382

Douglas Golick

Department of Entomology

ENTO 216, UNL, 68583-0816

IRB Number: 20170216732EX

Project ID: 16732

Project Title: Understanding Knowledge of Pollinator Health in Horticultural Retail

Dear Carter:

This letter is to officially notify you of the certification of exemption of your project for the Protection of Human Subjects. Your proposal is in compliance with this institution's Federal Wide Assurance 00002258 and the DHHS Regulations for the Protection of Human Subjects (45 CFR 46) and has been classified as exempt. You are authorized to implement this study as of the Date of Final Exemption: 2/17/2017

- Review conducted using exempt category 2 at 45 CFR 46.101
- Funding: Nebraska Environmental Trust - OSP Project ID 29199 Form ID 92623 Grant congruency completed by LA on2/17/2017

We wish to remind you that the principal investigator is responsible for reporting to this Board any of the following events within 48 hours of the event:

- Any serious event (including on-site and off-site adverse events, injuries, side effects, deaths, or other problems) which in the opinion of the local investigator was unanticipated, involved risk to subjects or others, and was possibly related to the research procedures;
- Any serious accidental or unintentional change to the IRB-approved protocol that involves risk or has the potential to recur;
- Any publication in the literature, safety monitoring report, interim result or other finding that indicates an unexpected change to the risk/benefit ratio of the research;
- Any breach in confidentiality or compromise in data privacy related to the subject or others; or
- Any complaint of a subject that indicates an unanticipated risk or that cannot be resolved by the research staff.

This project should be conducted in full accordance with all applicable sections of the IRB Guidelines and you should notify the IRB immediately of any proposed changes that may affect the exempt status of your research project. You should report any unanticipated problems involving risks to the participants or others to the Board.

If you have any questions, please contact the IRB office at 402-472-6965.

Sincerely,

Becky R. Freeman

Becky R.
Freeman, CIP
for the IRB

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